News

LHC Update: Technical Stop, 10 Year Plan, Back to Normal & New Luminosity Milestone

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Abstract

This news article contains LHC updates for the period of July 1, 2011 to July 30, 2011 which appeared in viXra Log at http://blog.vixra.org.

Key Words: LHC, technical stop, back to normal, 10 year plan.

July 5, 2011: For LHC Geeks Only

The Large Hadron Collider is currently in a technical stop following a very productive machine development break. Normal running has now brought the collider to its intended running parameters for this year with 1380 bunches per beam colliding at 7TeV centre of mass. With good fills the peak luminosity should be around 1.4/nb/s and there are 103 days of scheduled proton physics left this year. Assuming a reasonable Hübner factor of 0.3 this will be sufficient to provide 1.4*3600*24*103/nb = 3.7/fb. Add this to the 1.3/fb already delivered for a grand total of 5.0/fb in 2011. To put that in context here is the latest table of Higgs sensitivities.

ATLAS + CMS ≈ 2 x CMS	95% CL exclusion	3σ sensitivity	5σ sensitivity
1 fb^{-1}	120 - 530	135 - 475	152 - 175
2 fb^{-1}	114 - 585	120 - 545	140 - 200
5 fb^{-1}	114 - 600	114 - 600	128 - 482
10 fb^{-1}	114 - 600	114 - 600	117 - 535

5/fb is enough to exclude Higgs or find evidence for it up to 600 GeV (LEP has already excluded it below 114 GeV) This will be a tremendous result for the LHC and much sooner than expected. At yesterday's DG address to CERN staff Rolf-Dieter Heuer was keen to make it clear that a Higgs exclusion would be just as exciting as a Higgs discovery! At a CERN seminar today Carminati said that there will be an update on Higgs searches using 1/fb from ATLAS in two weeks time.

From the blog comments I know that there are a few of you out there who are interested in what more can be done to increase luminosity this year, so let's forget about the particle

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physics for now and see what the possibilities are for beam physics. Unless you are a hardened LHC geek you probably don't want to read any further.

I don't know everything that the beam operations teams are considering but the reports from the MD phase provide some interesting clues. Things should be much clearer after the "mini-Chanonix" meeting on 15th July. Some of you may be aware of points I missed so please do comment.

Not long ago it seemed most likely that very little would be done to increase luminosity this year, but the mini-Chamonix is purely dedicated to what can be done in the rest of 2011 and everything is on the agenda. The opportunities for luminosity can be summarised as follows

- Improved Hübner factor – Luminosity x 1.5
- reduced emittance by half – luminosity x 2
- bunch intensity to twice nominal – luminosity x 4
- ATS squeeze to 0.3m – luminosity x 5
- bunch spacing to 25ns – luminosity x2

So there is a potential increase in luminosity by a factor of 120! But no, it is not possible to do all these things at once until some major hardware upgrades are made. That will be for the High Luminosity LHC project a few years down the road. For now we need to look at these factors one at a time and see what combinations are possible and most desirable.

Hübner factor

This factor depends on how efficiently they can run the collider and how much of the time they can keep it in stable beams. I think it is not unreasonable to expect a Hübner factor of 0.3 in they keep all the parameters fixed and concentrate on improving efficiency. If they are lucky and things go very well an improvement up to 50% is conceivable, but if they decide to try out some more risky ways to increase luminosity then a lower Hübner factor is more likely, perhaps around 0.2

Reduced Emittance

The emittance is a measure of how well the protons keep going in a straight and narrow line. Better emittance means the protons in a bunch can be kept closer together. Halving emittance will double the luminosity. The nominal emittance is 3.75 μm, but by improving the injector chain they have found ways to get this down to about 1.7 μm . I dont know any downside of reducing emittance (anyone?). It does not lead to higher beam currents, just better luminosity. In that case it is a no-brainer that they will want to run with better emittance as soon as possible, isn't it?

Bunch Intensity

"Nominal" bunch intensity is 115 billion protons per bunch but they have already been running with up to about 125 billion protons per bunch. The "ultimate" bunch intensity was supposed to be 170 billion, but in an earlier MD slot they already pushed it beyond that to 195 billion. In the latest tests they went as far as twice nominal at 250 billion! Sorry that is

already too many exclamation marks for one post, but some of these numbers are really surprising. Nobody expected them to do this. How did they do it?

Luminosity goes up with the square of bunch intensity so this is a great way to increase luminosity, but there is a catch. Too much beam current is dangerous for the collider and the protection systems may not be sufficient beyond some limit. The cryogenics can also only take so much before the extra heat from the beams causes them to fail. Some increase in bunch intensity at 1380 bunches is possible, I don't know how much. To make use of the higher intensities that they can now reach they would have to decrease the number of bunches. For example, they could increase bunch intensity to 170 billion and decrease the bunch numbers to 1010. The total beam current would stay the same because it depends on bunch intensity times bunch number. But the luminosity would go up by 36% because luminosity depends on bunch intensity *squared* times bunch number.

The major downside of going for this option is that event pile-up increases. ATLAS and CMS already see about 8 events each time two bunches intersect. This goes up with bunch intensity squared, so for a 36% luminosity increase they get 84% more pile-up. High pile-up rates makes it hard to reconstruct individual events in the detectors. There will be more background and uncertainty in the numbers produced. It will be up to CMS and ATLAS to decide how much pile-up they want to take at this point versus the potential for more luminosity.

ATS squeeze

The Achromatic Telescopic Squeezing is a complicated system for modifying the optics to focus the beams better at the intersection points. It has been possible to squeeze down to beta* = 0.3m compared to 1.5m at in present use. This implies a factor of 5 in luminosity with no extra beam current! but that would require reduced crossing angles which means more parasitic collisions, especially if they increase bunch intensity. Realistically a factor of 1.5 might be gained this year using ATS without too much side-effect but this is unclear at the moment.

Bunch Spacing

Tests during the MD with injection at 25ns bunch spacing and 216 bunches have been encouraging. The smaller spacing would mean that they could increase the bunch number up to the nominal figure of 2808 bunches to double luminosity. The advantage of this over increased bunch intensity is that pile-up during bunch crossings is not affected so CMS and ATLAS would prefer it.

The downside is that they cannot increase bunch numbers and bunch intensity at the same time because it would mean too much beam current. The luminosity increases are not as dramatic as what can be achieved by bunch intensity increases alone. Again it will be the trade-off between pile-up and luminosity that must be considered.

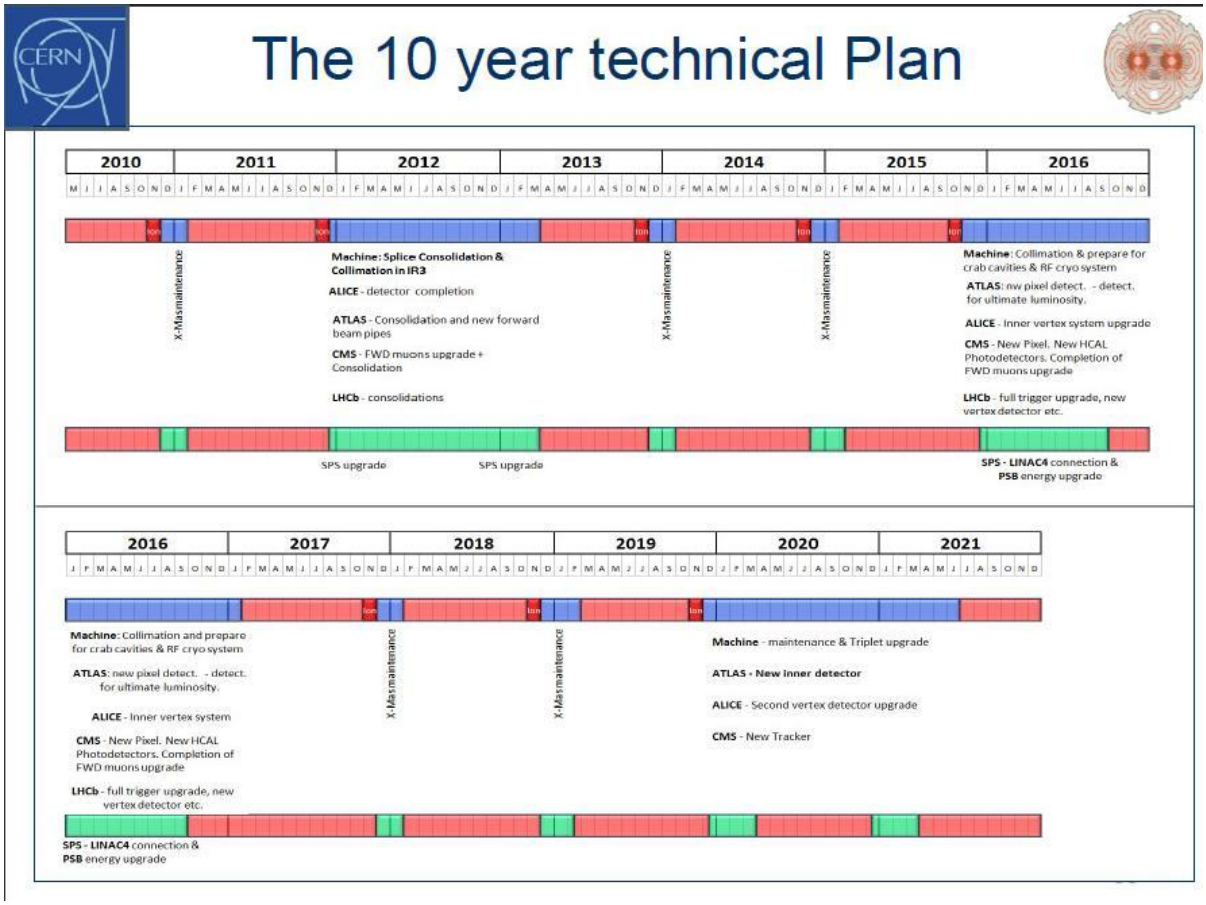
In any case I am not sure they are ready for 25ns spacing this year. Further tests during later MD slots are necessary. This step is more likely for next year.

Conclusions?

Details will become clearer at the mini-Chamonix. From what I have seen so far I think the best we can hope for this year is some modest increases in bunch intensity and emittance leaving them to concentrate on keeping a good Hübner factor. Some use of ATS optics towards the end of the year's run may be tried. A doubling of peak luminosity during 2011 is probably an option if general machine running os smooth enough and if CMS and ATLAS can take the extra pile-up.

For 2012 there is much more scope for improvements. I think they will go with 25 ns spacing and use ATS to increase luminosity further without exceeding beam current limits. Ten times luminosity is not beyond the realm of possibility so they could deliver 50/fb during 2012 at 9 TeV. Perhaps I am being too optimistic again. What do you think?

July 8, 2011: LHC Alternative 10 Year Plan

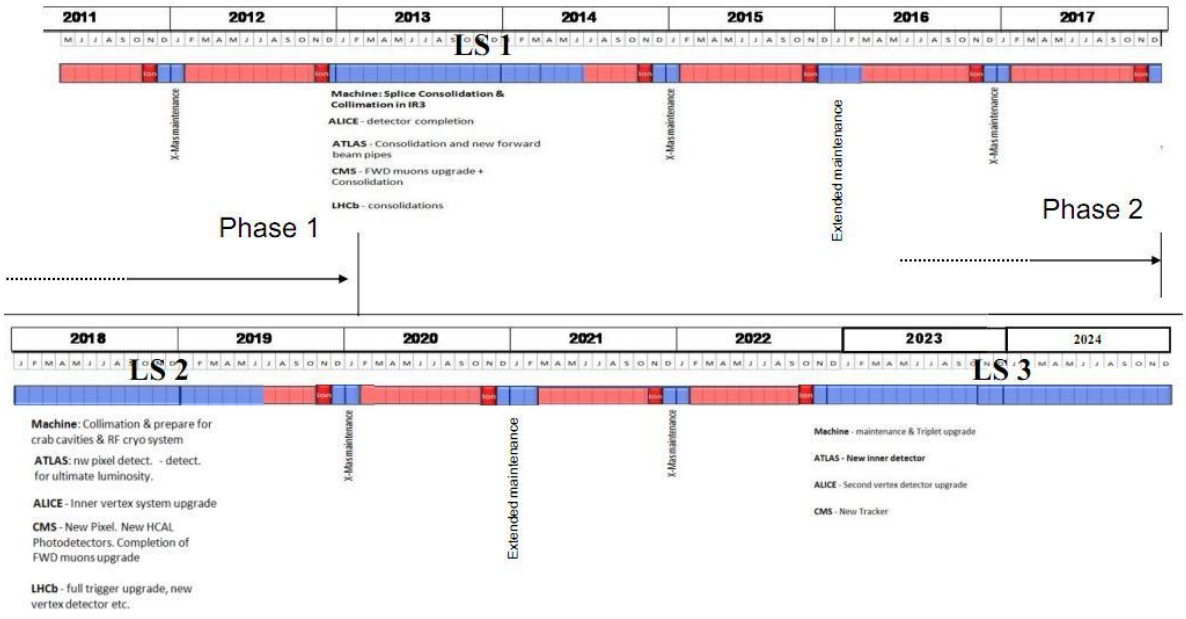


As viXra readers know very well, the current plan for the Large Hadron Collider is to run until the end of 2011, have a Xmas shutdown and then run again during 2012 with possibly

higher energy and luminosity. Then there will be a long shutdown to replace the magnet splices and make other upgrades so that it can run at the full 14 TeV energy from mid 2014. After a few more years there will be further long shutdowns with other upgrades leading eventually to the High Luminosity LHC.

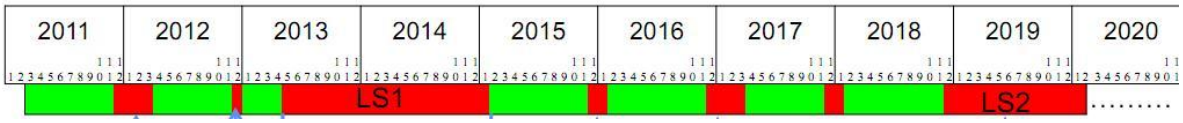
When this plan was accepted in July 2010 it looked like the above.

Since then the plan has evolved a little bit, with the long shutdown becoming a little longer and the later shutdowns being delayed further. The currently accepted plan looks like this (as always you can click on the image see a bigger version)



You will notice that there is now very little time for the run during 2014 so serious physics at 14 TeV cannot be expected until 2015.

Of course we have also learnt that LHC plans do not stay fixed for very long and it is now a poorly kept secret that this plan is also due for some major revisions. The latest provisional plan now looks more like this.



The change in plan starts at the next end of year shutdown when the usual two month is replaced with a longer 4 month period. This provides an opportunity for more upgrades, the nature of which is still obscure. Hopefully this improves the likelihood of the 2012 run being at an intermediate energy, 10TeV would be nice, but it may just be that there will be some essential detector upgrades during this break.

The extra delay means that the 2012 run continues well into 2013 until April. There is just a short two week stop over Xmas 2012. The long shutdown is pushed back even further with

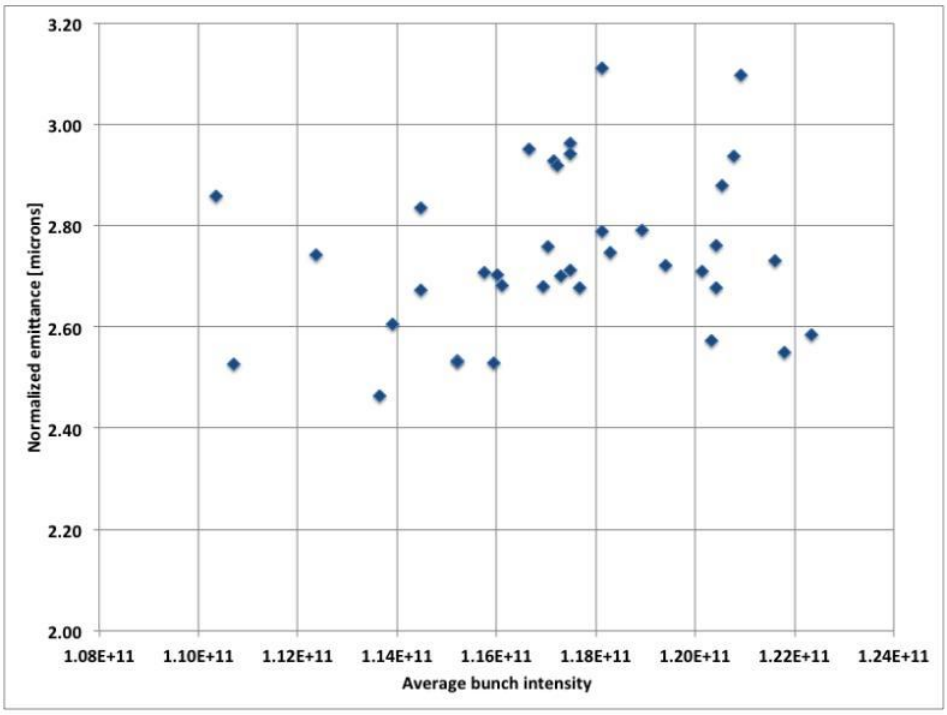
no 14TeV physics at all until 2015. The later date and the prospect of some very high lumniosity runs during 2012/2013 means that the detectors will be in need of some major work during the long shutdown while the splices are being replaced. We can now expect some of the major parts of ATLAS and CMS to be replaced with upgraded components, including the central beam pipes.

The delay of nominal energies may be disappointing but the prospect of better luminosity and possibly higher energy during 2012/2013 will certainly make up for it.

July 15, 2011: mini-Chamonix – back on for 10/fb in 2011

The Large Hadron Collider is quickly making its way back to normal physics runs after the technical stop and a power cut that knocked out the cryogenics for an extra couple of days. For a while we will be more interested in new results presented at the EPS conference in just six days time, but first the beams operation groups need to decide how they are going to run the collider for the rest of 2011. A one day "mini-Chamonix" has been organised for today to consider whether and how and by how much luminosity can be further increased. The presentation slides are available here.

There are 107 days remaining for proton physics this year. The most likely means for increasing peak luminosity further now is to increase bunch intensity and decrease emittance (i.e. the transverse spread of the beam over position and momentum space.) This plot shows the statistics so far.



In fact the intensity for the last run at 1380 bunches was 1.25E+11 and the emittance was about 2.8um. How much can this be improved?

Everybody now believes that 4/fb can be delivered to ATLAS and CMS this year and 1/fb to LHCb. This is just by running with present parameters and assuming a reasonable run efficiency, but more is possible.

Present peak luminosity is 1.28/nb/s. CMS and ATLAS would be happy to see that go up to 3/nb/s. Any more would provide more pile-up than they want at this time, but they would still want to go higher near the end of the run to test for ways to deal with high pile-up.

From the injection chain the best bunch intensity with multiple bunches this year is around 1.6E+11 protons per bunch with emittance of 2um. This would double the peak luminosity. Ways to go higher are being studied during MD time, but for next year.

As far as I can tell from all the other slides there are no barriers to these numbers from beam stability or machine protection considerations.

Other ways to increase luminosity such as 25ns bunch spacing and ATS squeeze are still under study. We may see more tests during MD but no real physics runs (with these new features) until at least next year (actually some more squeeze is still a possibility according to the conclusion)

We now just have to wait to see what they decide by the end of today.

Update:

The final conclusions are in and it looks promising. This is the table of possibilities they have to discuss.

So increasing intensity and decreasing emittance poses no risk and can be done gradually. A factor of 2.7 is then available. The experiments wont want much more than that so any further increases may result in luminosity leveling.

Luminosity comparisons are wrt 1380 bunch operation with 1.1E11ppb, emittance 2.7um, beta* = 1.5, Lumi = 1.2E33

Parameter and Criteria	adiabatic?	Estimated Max Lumi Improvement Factor	Lost Time for physics (days)	Risk/ Reversibility	Pile-up	Available Improvement factor (50ns)	Available Improvement factor (50ns)
ppb	yes	2	0	0	higher	Yes	No
emittance	yes	1.35	0	0	higher	Yes	No
beta*	No	1.5	3	>0	higher	Yes	Yes
25ns	No	1.9	7	>0	same	No	Yes
				Luminosity Factor		4.85	2.85
				Pile Up		33.95	19.95
				Estimated Relative Integrated Luminosity		364.2	193.8
				Relative Integrated Luminosity if we do nothing		90	

Conclusion

- Continue with 50ns
  - Operate with minimum emittance (2um)
  - Adiabatically increase the bunch intensity (max $1.55^{e}11$)
  - ? Reduce beta* to 1m
- Comment: under these assumptions (provided there is not a limit on pile up) there is no point in going to 25ns until after LS1.

The increases could be implemented over a 30 day period with 60 day left for running at full luminosity. Looks like 10/fb by the end of the year is back on.

July 18, 2011: Luminosity 1.6/nb/s for LHC

Since the end of the technical stop last week, the Large Hadron Collider has now worked its way back to fills with 1380 bunches in each direction. This evening it reached a new record peak intensity of about 1.6/nb/s beating the previous record of 1.28/nb/s.

So far about 56/pb have been added to the integrated luminosity since the stop. Most runs have been short with dumps due to UFOs and other glitches. The new record brings hope that the collider is getting back towards long clean runs and will soon be clocking up data at a faster than ever rate.

July 24, 2011: Quick LHC update

Since the LHC restarted after the last technical stop it has added about 210/pb to the integrated luminosity. In the last 5 days since returning to 1380 bunch fills more than 150/pb have been added which brings them back to the previous good production rate of about 30/pb per day.

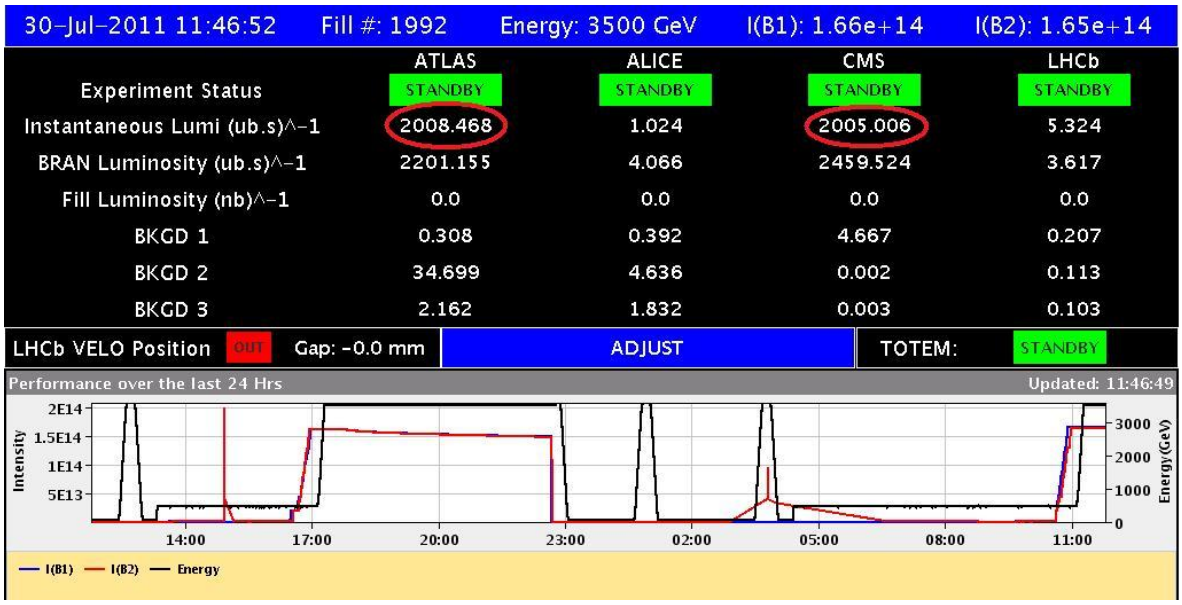
New records for peak luminosity were set last night with 1.75/nb/s during stable beams and 1.8/ns/s during the adjust mode of a run that was dumped before stable beams. Before the technical stop the record was 1.28/nb/s so significant luminosity increases have already been achieved. This has been mainly due to better beam emittance at about 2.4 um in the lastest runs. The bunch intensity is still being held at 120 billion.

There are many problems causing beams to be dumped including UFOs, cryo, vacuum, RF and power glitches. However it has been possible to recycle and return to stable beams relatively quickly to keep the data flowing. Unless they can improve the stability they may have to reconsider the plan to increase bunch intensity because that would mean more cryogenic outages that can stop the runs for one or two days at a time.

Steve Myers will give a status report at EPS in a plenary session on Wednesday that is due to be webcast.

July 30, 2011: New Luminosity Milestone for LHC

The Large Hadron Collider has today surpassed 2000/μb/s in peak luminosity for both ATLAS and CMS. This was achieved during the Adjust phase of fill number 1992 using 1380 bunches per beam, just before stable beams were declared this morning.



Luminosity has been gradually increased above the 1280/μb/s limit reached before the technical stop at the end of last month. So far only emittance has been used to enhance the luminosity. This does not increase the overall intensity of the beams so there is no increased risk or extra demand on the cryogenics. At the recent mini-chamonix meeting it was predicted that emittance could provide an extra 35% luminosity but now they are 55% above where they were before. This extra is probably just due to the fact that the final runs before the technical stop suffered from some emittance blowup or injection losses that meant they were not as good as they could have been.

It was intended that further luminosity improvements would be attempted by increasing bunch intensity. This has the potential to double the peak luminosity again. This plan has been held back because of the technical difficulties of running at the high intensities they are now using. This can effect the vacuum and cryogenics leading to premature dumping of the beams and increasing times for returning to stable beams. Indeed the current rate of luminosity delivery is around 35/pb per day, just slightly better than the 30/pb per day when they ran with 1092 bunches during June. The proportion of time in stable beams recently has only been about 30% but there are signs that this is getting better.

There are just 24 days left before they break for the next Machine Development slot and the beam operation groups will be keen to make further progress with both stability and luminosity during that time. With 1.75/fb now delivered they are already on target to reach 2.6/fb at the next technical stop. After that there will be a final run lasting eight weeks before they switch from proton physics to heavy ions for they last part of the year. It is not yet clear at what point the experiment collaborations will decide to update their analysis but clearly this level of data is guaranteed to have enormous impact, especially on the Higgs searches.